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SOME AMATEUR OBSERVATIONS ON COLOR-FORMS

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When the botanizer whose activities are, like those of most of us, confined to a comparatively limited area begins to feel the pressure of the law of diminishing returns—when it becomes harder and harder to find unfamiliar species or even new stations for rare ones and he looks about for some new world to conquer—then the study of the variations of color in flowers of the same species offers a field of observation in which little has been done. That this is the case is doubtless because color-forms have to be studied in fresh material and, since they are comparatively rare, it is hard for any one investigator to get hold of any very large number of them in the proper condition. But if many amateurs, each in his own locality, would even list and, so far as possible, classify those which come under their eyes, the combined lists could hardly fail to add considerably to our knowledge in this direction. It is with the hope of starting some such composite list that I have ventured to set down the results of my own scattered observations.

By color-forms I do not mean the slight variations in shade, often due to differences in intensity of light, which occur in all colored flowers, but marked and striking changes in shade or hue—marked, at least, in their extremes, for they may be connected by intermediates with the typical forms. The searcher after such variants will presently notice that they tend to fall into groups—that flowers of a certain color will vary in one direction and not in another. So far as my experience goes, I can distinguish five lines of color variation, enumerated below. Under each I have listed such examples of it as I have actually seen.

1. Any flower of strong color is likely to develope paler variants. These are doubtless due to a weakening of the pigment; they do not, however, appear to be due to weak illumination, for they occur side by side with the usual, strongly colored forms. They give no real change of hue from the latter, but are often of strikingly different appearance. Such forms are *Aquilegia canadensis* with the usually red parts of the flower a delicate salmon-pink; pink *Lobelia cardinalis;* pale blue *Campanula rotundifolia;* and pale yellow or cream-colored forms of such usually orang or bright yellow blossoms as *Impatiens biflora*, *I. pallida*, *Gratiola aurea*, *Lysimachia terrestris*, *Hypericum punctatum*, and *Potentilla pumila*.

2. Albinos—the commonest and best-known kind of color-forms. Here, however, Dr. Gray's *nota bene*, that white forms of all colored flowers are to be expected, seems to need emendation. Such forms, pure white and destitute of any trace of color, are to be expected in all blue, purple, magenta, and pink and in some crimson, flowers. I have seen them, to cite a few cases, in *Campanula rotundifolia*, *Hepatica americana*, *Sisyrinchium atlanticum*, *Lobelia spicata*, *Habenaria fimbriata*, *Geranium maculatum*, *Monarda mollis*, *Epilobium angustifolium*, *Rubus odoratus*, *Agalinis purpurea*, *Teucrium canadense*, and *Sabatia stellaris*. But I have never seen a really white form of any scarlet, orange, or yellow flower. Such a form has been credibly reported in *Gratiola aurea* and there are at least two records of white forms of *Impatiens biflora*. One of these I ran down and was informed by its author that though he had heard of white flowers in the species, all he had actually seen were cream-colored. It seems safe to assume that albinism is, at the very least, much rarer in flowers of the yellow than in those of the blue-pink series. The same tendency seems to exist, or better, persist, in cultivated plants. Take up any seedsman's catalogue and you will find that in practically all flowers which were originally blue, purple or pink, white forms are advertised; but you will see no mention of white coreopsis or marigolds or sunflowers. When, as in the case of the California poppy, wall-flower, and nasturtium, pale forms occur, they are described as "whitish" or "creamy white," not "pure white" or" paper white," as in the other series. And this would seem to parallel quite exactly what takes place in the wild.

3. The reverse of albinism—cases in which normally white or greenish flowers develop color. This variation occurs in two directions. Normally white or greenish flowers may become more or less flushed with pink, as in *Dicentra Cucullaria*, *Anemone quinquefolia*, *Rubus alleghaniensis*, *Circaea latifolia* and *Daucus Carota*, or even deep red, as I have seen them in *Vaccinium vacillans*, or purple, as in *Daucus Carota*. Or normally white flowers may develop a cream-colored pigmentation. I have seen but one case of this, in *Habenaria blephariglottis*. Similar forms of this species have been regarded as hybrids with *H. ciliaris;* but my specimens were found at South Windsor, Conn., where the latter is wholly unknown.

4. Blue or purple to pink, as in *Trichostema dichotomum*, *Aster novae-angliae*, *Lupinus perennis*, *Hepatica americana*, *Linaria canadensis*, and *Prunella vulgaris*. The reverse change, from pink to blue, does not seem to take place in our region and perhaps not in nature—the impossibility of a blue rose or a blue orchid is proverbial. In certain *Boraginaceae*, however, as is well known, the bud is pink and the mature corolla blue in the same flower, and in *Desmodium marilandicum* and related species the magenta flowers take on when withering a peculiar greenish blue.

5. Crimson or scarlet to yellow or vice-versa. *Lilium philadelphicum*, *L. canadense*, *Castilleja coccinea*, *Trillium erectum*, *Corallorrhiza maculata* and the red or yellow portions of the flower in *Aquilegia canadensis* and *Pedicularis canadensis* are examples. This change takes place in both directions: *Lilium philadelphicum* has a beautiful clear yellow form and *L. canadense* a red one rather common in some localities.

If one carries curiosity further and asks what causes color-forms and by what process they arise, his quest for a satisfactory answer is likely to be long. One thing seems wholly probable, almost certain—that they are not produced by external conditions. They occur ordinarily in the closest association with the typical forms of their species. I once thought indeed, that I had detected a difference in the specific acidity of the soils in which certain color variants and the typical forms near by grew, but the difference held only for the first three or four cases tested: in the next three or four it broke down. Whatever the cause may be, it is apparently something internal and physiological,

perhaps merely functional, resulting in chemical action which either stops the production of the usual pigment partially or altogether, or changes its color.

What the chemical action is, must be left to the experts to discover. The amateur can, however, make, after a fashion, solutions of flower-pigments, try their reactions to acid and alkali and thereby gain some rough idea of the kinds of pigment concerned in the different changes. These tests are pretty work; the colors obtained are often very brilliant and beautiful. They can be made–indeed, in view of the uncertainties of getting delicate petals home in good condition, they are often best made —in the field. The modest apparatus needed is not very cumbersome to carry, especially if one has the use of a motor-car to carry him near to the theater of operations. My own outfit packs nicely into a small old travelling bag about a foot long. It consists of a pint bottle of distilled water, a smaller bottle of alcohol (grain alcohol if you can get it), a can or two of sterno, matches and two test tubes for making solutions; a large glass rod for handling or macerating petals in the test-tubes; a small vial of concentrated hydrochloric acid, one of concentrated ammonia and two small glass rods for transferring drops of these reagents to the pigment solutions; a few half-ounce homoeopathic vials in which to make the tests; and a note-book for recording results. Solutions are made by boiling petals for a few seconds in distilled water in a test–tube held over the sterno, or by soaking them for a few minutes in alchohol. One method is best in some instances, the other in others. In case of doubt, try both, as I usually do. If your supply of canned heat gives out, a rather weak and murky, but usable solution may be made, in some cases, by macerating the petals in cold water. Occasionally this gives a somewhat different result from the boiled solution; it might be worth trying sometimes as a check. Only very small quantities of the solutions are needed; the less water or alchool one uses in proportion to the bulk of petals, the stronger in color and better will be the solution obtained. When the solution is ready, part of it is poured into one of the small vials, a drop of acid added and the resultant color-change, if any, noted. Another portion is placed in another vial and a drop of ammonia added to it. If acid changes the color the original hue can often be brought back by adding enough ammonia to neutralize the acid; and vice versa.

I have generalized somewhat freely in giving these directions; as a matter of fact, the tests I have actually made are so few (and I am so far from being a chemist) that it is with some trepidation I write about them at all. Nevertheless, so far as they go, they give apparently consistent results. They show four types of reaction, as follows.

A. Solutions from the petals of white flowers, whether normally so or albino forms, give, as might be expected, almost wholly negative results. They are unchanged with acid and slightly yellowed with alkali.

B. Solutions from blue, purple, magenta, pink, and red flowers turn pink or red with acid or retain those colors if they had them originally. With ammonia they turn first a greenish blue (or bluish green (it is hard sometimes to tell just what to call this color) changing presently to greenish yellow, pale yellow, or to an almost colorless condition. If too much ammonia is added, the yellowish color appears at once without the intervening greenish or bluish stage. These are, of course, well-known anthocyan reactions. Since anthocyan pigments occur dissolved in the cell-sap and flowers of this series make almost equally good solutions in water and in alcohol (and probably would in any neutral liquid which would mix with water), and since the colors of the flowers are anthocyan colors, it seems safe to assume that we have here cell-sap pigments of that class. The change of the solution from blue to pink with acid is exactly what occurs when the hepatica, for instance, develops a pink form; the change to greenish blue with ammonia parallels that in the withering flowers of *Desmodium*. It would appear, then, that this type of color variation occurs in flowers having anthocyan pigments, that pink forms of normally blue flowers develop in individuals in which the cell-sap is, for some reason, more acid than is usual in the species, and that, as was long ago postulated for boraginaceous flowers which are pink in the bud and blue when mature, an alkaline condition develops in the withering flowers of the *Desmodium*.

C. Solutions from some yellow flowers are unchanged with acid (at least at first; I am not sure that they might not turn green if left to stand for several hours) and slightly deepened in color with ammonia. Since these flowers do not give good solutions with water but only with alcohol, their pigments may

be assumed to be of the plastid type—that is, they occur, as chloropyll does, in small particles which are nearly or quite insoluble in water but more readily soluble in alcohol or other solvents of fat.

It may be noted that the flowers which give anthocyan reactions are precisely those in which albinism is commonest; it is at least very rare in those giving plastid reactions. It would seem, then, to be a phenomenon associated with anthocyan rather than with the apparently more stable plastid pigments.

D. Certain other yellow flowers give about equally good solutions in water and in alcohol; these are unchanged, or practically so, with acid but turn a brillant deep red with ammonia. This reaction I have happened to see only in *Coreopsis lanceolata.* The color produced with ammonia is essentially the same as that which occurs at the base of the rays in other species of *Coreopsis*, in some color-forms of *Rudbeckia hirta* and in some of the western cone-flowers. Probably we have here the third of the "fundamental" plant pigments listed in the books—an unnamed, primarily yellow pigment occurring dissolved in the cell-sap.

The change from yellow to red with ammonia resembles the color variation in *Trillium*, etc., described in paragraph 5 above; but it is not what happens in those cases. Typical *Trillium erectum* and *Castilleja coccinea* and the red form of *Pedicularis canadensis* give the regular anthocyan reaction as in B. The yellow forms of all these give the plastid pigment reaction as in C. A solution from bracts of *Castilleja coccinea* which had been boiled until all the red color had disappeared also gave the C reaction. I could not get as clear-cut results from the *Trillium* or the *Pedicularis;* in them, the boiled petals continued to give a weak anthocyan reaction. Nevertheless it seems to me likely that in all these cases, as with the xanthophyll and erythrophyll of autumn leaves and other instances described in the books, two pigments are concerned, a red anthocyan and a yellow plastid. The latter is masked by the former when that is present, but comes into its own when for any cause the anthocyan is withdrawn.

How much value the results of these rough and simple tests have, the experts must determine. But they seem to be consistent and coherent as far as they go; and the getting of them is good fun. I recommend it to anyone in search of new ways of botanizing.

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